LAWES AGRICULTURAL TRUST

Rothamsted Experimental Station
Harpenden

Annual Report for 1914

with the

Supplement

to the

"Guide to the Experimental Plots"

containing

The Yields per Acre, etc.

In every case the page, table, and plot numbers refer to the "Guide" 1913, it being understood that no change is made in the manuring, etc., there described

E. J. RUSSELL, D.Sc., Director

HARPENDEN:
PRINTED BY D. J. JEFFERY, VAUGHAN ROAD
1915

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INTRODUCTION

John Bennet Lawes was the founder of the Rothamsted Experimental Station. He began experiments with various manurial substances, first with plants in pots and then in the field, soon after entering into possession of the estate at Rothamsted in 1834. In 1843 more systematic field experiments were begun, and the services of Joseph Henry Gilbert were obtained as Director, thus starting the long association which only terminated with the death of Lawes in 1900, followed by that of Gilbert in 1901.

The Rothamsted Experimental Station has never been connected with any external organisation, but was for many years maintained entirely at the cost of the late Sir John Lawes. In 1889 he instituted a Trust for the continuance of the investigations, setting apart for that purpose the old laboratory (which had been built by public subscription, and presented to him in 1855) certain areas of land on which the experimental plots were situated, and £100,000.

By the provision of the Trust Deed the management is entrusted to a Committee nominated by the Royal Society (four persons), the Royal Agricultural Society (two persons), the Chemical and Linnean Societies (one each), and the owner of Rothamsted.

Mr. A. D. Hall was appointed Director in 1902 and held the position till he resigned in 1912, when the present Director, Dr. E. J. Russell, was appointed. Mr. Hall brought about great developments, re-organising the work, increasing the staff, and considerably extending the buildings and laboratories. In 1906 Mr. J. F. Mason, M.P., presented the Committee with £1,000 for the building and equipment of the "James Mason" Bacteriological Laboratory, together with an annual grant towards its maintenance. In 1907 the Goldsmiths' Company made a grant of £10,000, the income of which is devoted exclusively to the investigation of the soil. The Permanent Nitrate Committee also made a grant of £2,000 to the endowment. In 1913 Lady Gilbert presented the library of the late Sir J. Henry Gilbert. The Hon. Rupert Guinness provides funds to maintain a special research chemist. The collection of smaller donations and annual subscriptions is the work of the Society for extending the Rothamsted Experiments which was founded in 1904, and the sums thus obtained provide a valuable contingency fund.

During the year 1911 a scheme was published from the Board of Agriculture for the encouragement of agricultural research with funds provided by the Development Commission, and this scheme established or assisted a certain number of institutes for fundamental research, each dealing with one great branch of the subject. The Rothamsted Experimental Station is recognised as the Institute for dealing with Soil and Plant Nutrition Problems. In accordance with this scheme an annual grant of £2,500 was made, which has this year been increased to £2,850.

Besides the regular staff, a number of post graduate workers and holders of scholarships carry out their investigations at Rothamsted, and investigators from other institutions periodically spend a certain amount of time in the laboratories studying

analytical methods or ways of getting over difficulties that have arisen in the course of their work.

These developments necessitated a considerable extension of the laboratory and of the farm. The first steps consisted in taking over 230 acres of land in 1911 on a 77 years' lease, and this, together with the Trust land, gave a self-contained farm capable of being worked with great advantage to the experiments. Suitable farm buildings and cottages were erected in 1913. A new wing was also added to the laboratory, and this was opened on June 27, 1913, by the Rt. Hon. Walter Runciman, M.P., President of the Board of Agriculture.

In 1914 the old laboratory, which had for some time revealed certain structural defects, was taken down and a new laboratory was begun, to commemorate the centenary of the birth of Sir J. B. Lawes in 1814 and of Sir J. H. Gilbert in 1817. Altogether these improvements cost over £21,000, of which £10,000 was given in grants from the Development Fund and over £9,000 collected by public subscription; of this £6,000 was obtained as the Lawes and Gilbert Centenary Fund in 1914.

The field experiments, which began in 1843, have on some of the plots been continued without break or alteration up to the present day; on the Broadbalk Wheat Field certain rearrangements were made in 1852, in which year also the Barley experiments on the Hoos Field began. The leguminous crops on the Hoos Field were started in 1848, the experiments on Roots have been continued on the same field since 1843, and on the same plan since 1856. The grass plots began in 1856, and the rotation experiments in 1848.

It is impossible to exaggerate the importance of continuing the experimental plots at Rothamsted without any change, as nowhere else in the world do such extensive data exist for studying the effect of season and manuring upon the yield and quality of the crop, and for watching the progressive changes which are going on in the soil. Year by year these plots are found to throw light upon new problems in Agricultural Science; in all directions they continue to provide material for investigations upon points which were not contemplated in the original design of the experiments, so that it is impossible to foresee when and how they will not become useful and provide indispensable material for the solution of problems undreamt of at the present time.

The maintenance, however, of the old data throws a heavy burden on the Experimental Station. There are 210 plots, and every year 243 samples have to be taken with proper precautions and put into store for future reference. In addition, many analytical determinations are made. During the past and the present season complete soil samples are being taken for analysis, to enable a comparison to be instituted with the set of samples taken in 1894, and thus to study the soil changes that have gone on during the last twenty years. A complete botanical analysis of the grass plots is also in hand.

It should be remembered that the object of the Rothamsted Experiments is to study the soil and the crop, and only indirectly to find the most paying method of manuring; hence neither the nature nor the quantities of material applied are to be taken as indicating the manures which should be used in practice.

ANNUAL REPORT

FOR THE YEAR 1914

THE outstanding feature of the year 1914 in the annals of Rothamsted will always be the pulling down of the old laboratory that has done duty for 60 years, and the commencement of the new laboratory where future work will have to be carried out. At this stage in the history of the station it is opportune to summarise briefly the nature of the present day work and its bearing on the development of agriculture.

The general character of the work is determined by the very prominent part played by the teacher and the expert in recent agricultural developments. At no time has there been so large a number of experts engaged by Government Boards, County Councils, Societies, etc., for the purpose of giving advice to farmers, and at no time has there been a more wide-spread demand for agricultural education.

But before the expert adviser and the teacher can do their work satisfactorily it is obvious that definite systematic knowledge must be obtained of the subject with which they have to deal. Until this has been done much of their teaching must be purely conjectural and may even be unsound—the history of the subject is full of illustrations in point. The only safe foundation on which their work can be built up is sound, accurate knowledge gained by systematic investigation.

The proper function of a Research Institute is to obtain such knowledge and to develop an agricultural science that teachers can teach and experts can use. The true test of the work is not its immediate applicability to practice but its significance in the development of agricultural science.

Agriculture covers so wide a field, and the movement towards specialisation tends to become so pronounced, that no one Institute can deal with the whole subject, and at Rothamsted the work is now confined to:—

(1) The study of the soil conditions that affect the growth of the plant;

(2) The nature of the changes induced in the plant by variations in soil and nutrition conditions.

Thus the investigations cover the whole of the problems involved in Soil Management and Crop Production.

Two general methods of investigation are adopted—the operations of the best practical men are studied; and experiments are made to discover precisely what the plant wants from soil and what conditions are necessary in order that it may get what it wants. The first often furnishes useful ideas, but the second generally gives more precise information and has in our experience proved more fruitful. Several instances could be quoted: an investigation on the rate of oxidation in soils—apparently a highly academic enquiry very remote from practice—led direct to the explanation of the phenomena of "sickness" in glasshouse soils, a problem bristling with so many difficulties that it could hardly have yielded to any

direct attack. The growers concerned were so satisfied with the results that with the aid of the Board of Agriculture they have set up an Experiment Station in their midst where other of their problems can be investigated.

The laboratory experiments do not conclude an investigation: pot experiments are made to test any conclusions bearing on the growth of plants and, if these indicate a sufficiently important bearing on farm practice, they are followed by small plots, and then finally by larger plots to show to farmers, or demonstration pots on a practical scale for horticulturists. In this manner a green manure rotation experiment has this year passed from the pot culture house to the demonstration plot stage. Further, in order to broaden the outlook, investigations are periodically carried on outside Rothamsted; these, however, necessarily deal with special cases where ordinary methods fail, and as a preliminary they usually require the working out of new methods of attack.

In dealing with problems of soil fertility agricultural chemists for some years confined themselves largely to one aspect only: the supply of plant nutrients. The experiments made by County Councils and other experts were almost entirely restricted to this phase of the problem, and when a soil was sent in for analysis the advice given commonly had reference only to the suitability of certain artificial manures.

It soon appeared, however, that other factors had also to be taken into account, and that the ordinary soil analysis or manurial demonstration in itself was insufficient to give the help the farmer was justified in asking. The water and air supply, the tilth, and the soil type were equally important, and they are now claiming considerable attention from the investigator.

The water supply is a factor of the first importance in determining not only the growth of plants but also of micro-organisms, the activity of which has been shown in previous reports to play so large a part in soil fertility. It can be modified by suitable cultivations and manures, but, notwithstanding its vital importance, it has not proved easy to study. A considerable mass of data has been accumulated at Rothamsted showing the percentage of water in soils under various conditions, but it was impossible to discuss the results adequately because we did not know in what state the water existed in the soil. Physical investigations made elsewhere indicated that the water was present as free films merely suspended on the particles just as sea water is suspended on grains of sand or as oil on leaden bullets. This view had the advantage of simplicity, and it allowed deductions to be made direct from the known laws of evaporation, diffusion, etc.; but several field observations indicated that it was not correct. It was useless to go on multiplying field observations when we could not deal with those we had already got, and Mr. Keen accordingly began on this problem directly he took up his post as Goldsmiths' Company's Soil Physicist. The method adopted was to study the rate of evaporation of water from the soil. The relationship of water to soil was found to differ considerably from its relationship to sand. The soil colloids diminish the tendency to evaporation: the effect is so definite that it can be represented by a mathematical formula from which a curve can be drawn that agrees entirely with the experimental curves. One of

the most interesting results is that all the water in a normally moist soil is held in the same way and there is no break in physical state: the distinction that used to be made between free water and hygroscopic water could not be found in these experiments. The agreement between the experimental curves and those deduced from the formula shows that we have now got at the various factors involved and can proceed to work up our field results.

Equally important with the water supply is the air supply in the soil: this has been under investigation in conjunction with Mr. Appleyard. Periodical analyses extending over nearly two years on several typical plots have shown that the free air in the soil pore spaces differs only slightly from atmospheric air in regard to oxygen content: there is, however, a greater difference in carbon dioxide content. These results agree so closely with those obtained elsewhere that we may regard the similarity of soil air to the atmosphere as generally true. But the investigation revealed something that has not before been observed. It was found that in addition to the free air of the soil there is a second atmosphere dissolved in the soil moisture and colloids, which is entirely different in composition; containing *no* free oxygen but mainly carbon dioxide and some nitrogen. It is this atmosphere which is in most intimate contact with the plant roots and micro-organisms, and its lack of oxygen proves that the oxygen is used up more rapidly than it is renewed by solution from the free air.

These results have materially helped our investigations on the biochemical changes in the soil. It has been explained in previous Reports that the nitrogen compounds occuring naturally in the soil or added as manure break down under the action of micro-organisms to form nitrates and gaseous nitrogen; the former being wholly valuable and, in this country, commonly limiting the fertility of the soil; while the latter is wholly waste and, so far as can be seen, of no value whatever to the cultivator.

The study of these changes is perhaps the most important of soil fertility investigations. Much of the work in the past has been done in the laboratory, but this year it has become possible to carry the investigation into the field. During the past five seasons periodical determinations have been made of the amount of nitrate present in soils under varying treatments. When these results are set out it is found that the rate of accumulation of nitrates is usually rapid in spring, falls off in summer, rises in autumn, and falls again in winter: thus two maxima occur: one in spring and the other in autumn, while the minima occur in summer and winter. Unfortunately, however, the amount of nitrate in the soil at any time only represents the balance of gains over losses and cannot be taken offhand as a measure of the rate of *production* of nitrates, the quantity that is really wanted. For some time we could see no way of getting over the difficulty, but a simple solution was ultimately found. It is evident that if the curves showing the amount of some other substance *produced in the same way as the nitrate but lost in a different way* are of the same general shape as the nitrate curves then the shape is due mainly to the production factors; if on the other hand the two sets of curves are different in shape then the loss factors control the situation. The carbon dioxide in the soil air satisfies these requirements: it is produced like nitrates

by bacterial action, but it is lost largely by gaseous diffusion and only in very wet weather by leaching. Carbon dioxide was therefore determined simultaneously with nitrates, and the curves show a marked similarity except that the increases in nitrate came later. Thus we may conclude that the curves are in the main *production* curves.

In winter the curves follow the temperature pretty closely, but through the rest of the year they follow the rainfall and to a less extent the moisture. There is evidence that the dissolved oxygen in the rain may be a factor of importance particularly as it ensures renewal of the dissolved atmosphere. After a heavy rainfall the carbon dioxide in the soil air begins to increase followed later by an increase in nitrates. A certain number of bacterial counts were made, and these showed that a rise in bacterial numbers preceded the autumn increase in carbon dioxide.

A series of field experiments has been started to ascertain how these spring and autumn periods of biochemical activity may best be utilised for crop production.

The other reaction, the loss of gaseous nitrogen from the soil, is under investigation in the laboratory, but we anticipate that our main guidance will come from the parallel investigation of a manure heap which is being made simultaneously by Mr. E. H. Richards, the Hon. Rupert Guinness Research Chemist. These experiments have indicated a hitherto unsuspected source of loss in the heap and, fortunately, a way of avoiding it. Mr. Richards finds that nitrates are formed on the outside of the heap, but readily decompose if they are washed inside. Watering a heap sufficiently to effect this but not enough to cause leaching was found to increase the loss considerably; on the other hand shelter from rain, together with compacting, reduced the loss practically to zero over a period of three months' storage.

The technical value of this work is very considerable, but of even greater significance is its application in elucidating the loss of gaseous nitrogen from soil. In at least one direction a soil particle containing organic matter resembles a manure heap: it is surrounded by a free atmosphere containing some 20 per cent. of oxygen so that nitrate production goes on at its surface; it also has a dissolved atmosphere devoid of oxygen and therefore supplying one of the essential conditions for denitrification. This resemblance furnishes a working hypothesis which is now being developed.

The activity of the micro-organisms of the soil is dependent on two other factors besides those already mentioned. A source of energy is obviously indispensable: this is provided by the residues of plants and is, indeed, one of the most interesting of the inter-relationships between plants and soil micro-organisms. The other factor is the presence in the soil of sufficient basic material which in practice always means a sufficiency of calcium carbonate.

The precise effect of this substance has still to be determined, and pending the completion of Mr. Horton's investigations it is safest to follow the practical man and speak of soils as "sour" when calcium carbonate is lacking. "Sour" soils are commonly infertile. The method of overcoming the trouble is to add either lime or chalk. Dr. Hutchinson and Mr. MacLennan find, however, that lime differs fundamentally from chalk in its action. Lime is a partial sterilising

agent, chalk is not. Lime begins by depressing bacterial numbers and protozoa: later on, however, it is converted into chalk and the bacterial numbers begin to rise with production of ammonia in the usual way. This distinction in biological effect, in addition to the distinction in chemical effects, afforded a satisfactory explanation of some of the discrepancies observed in practice. A method was devised for rapidly determining the quantity of lime required per acre; pot experiments showed that the results are reliable. A further method was worked out for determining the amount of calcium carbonate (or of lime) needed to correct "sourness" and ensure an ample supply of base for the needs of bacteria and plants.

The zoological study of the soil protozoa has continued, and Mr. Lewin has further developed the methods which Mr. Martin and he have been using for demonstrating the existence of an active protozoan fauna in the soil. In conjunction with Mr. Martin he has published an account of two of the more interesting types of amoebae that are found in the trophic state. Mr. Goodey has also published an account of three new amoeboid organisms obtained from the soil and apparently widely distributed, that feed on bacteria and other small forms. They are remarkable for their large size, one of them varying up to no less than 1 m.m. in breadth. Our interest in these organisms is to study their activities in the soil: the work is very difficult, but satisfactory progress is being made.

It has already been pointed out that ordinary soil analysis often yields incomplete information through ignoring the other factors essential to soil fertility. There is, however, another source of trouble well recognised by experts: the selection of a method of extraction.

The first methods, founded wholly on mineral analysis, proved of little value in this country. A marked improvement was effected when dilute acids were substituted for strong acids, but many anomalous cases still arose. The underlying assumption always was that the soil was a mass of mineral fragments with the phosphates in the ordinary mineral form. We have seen that this view led to a wholly inaccurate conception of the water relationships of soil. In like manner all attempts to interpret the action of dilute acids on soil phosphates as an ordinary chemical reaction have failed. This year Mr. Prescott has studied it in detail and finds that it includes two separate changes.

The first action is that of the acid on the phosphate, which, so far as can be gathered, is normal, resembling the ordinary action of acid on any other phosphate. But almost instantaneously there appears another action which gives its distinctive character to the behaviour of the soil: an absorption of the dissolved phosphoric acid. This absorption closely resembles the adsorption shown by colloids, and is entirely expressed by the ordinary adsorption formula generally attributed to Freundlich: the agreement is so satisfactory as to afford strong presumptive evidence that the main features of the reaction are accounted for.

The reaction between dilute acids and soils thus appears to be essentially a displacement of absorbed material by something which is itself absorbed; and it falls into line with other displacements from colloids.

If this view is correct it follows that acids need not be used in soil analysis at any rate for the extraction of bases: any agent capable of being absorbed by the soil would serve equally well. In our laboratory Mr. J. A. Hanley has recently been using a solution of ammonium nitrate and finds it dissolves at least as much potassium, calcium, etc., as an acid, and in some respects is more satisfactory. This method of extracting the bases from soils was devised by Prof. Ramann, under whom Mr. Hanley worked for a time.

These investigations promise to clear up many of the difficulties in soil analysis.

THE PLANT NUTRITION WORK.

The fundamental problem in plant nutrition is the production of sugar in the green leaf, but the investigation is seriously hampered by analytical difficulties. During the past three years considerable improvements in method have been effected by Mr. Davis and his assistants, Messrs. Daish and Sawyer, and this year satisfactory proof has been adduced of the presence of free pentoses in the leaf and a method has been elaborated for determining them.

The complete method now allows of the determination of cane sugar, maltose, dextrose, levulose, pentoses, starch, and pentosans in the leaf. It has been used for numerous analyses of leaves and stalks plucked at regular intervals during the day and night, the results of which will be discussed later.

Equally important from the standpoint of crop production is the formation of starch in the grain. Analytical difficulties have hitherto prevented a satisfactory investigation, but this year the determination of starch has been put on a satisfactory basis. The existing methods may give rise to an error equal to 20 per cent. or more of the starch present: in the ordinary diastase method, for example, a loss of this magnitude may arise from the precipitation of dextrin during the preliminary processes of precipitation. A new method has therefore been devised, based on the fact that the enyzme taka-diastase transforms starch quantitatively into maltose and dextrose, no dextrin being formed: thus the errors of the ordinary method are obviated. This is apparently the only trustworthy way of estimating starch in plant tissues, and it is now being used for wheat and barley grown on the Rothamsted plots.

During the year Dr. Brenchley has been engaged on an extended survey of the grass plots; a complete botanical analysis is being made, and the results are compared with the last survey of 1903 and the earlier ones of 1862, 1867, 1872 and 1877 in order to follow the change brought about in the herbage. A survey of the weed flora of certain of the fields, and of the flora of Geescroft and the Wilderness, has also been made and compared with that of earlier years. All these results are being worked up both from the agricultural and the ecological standpoints.

The investigations on the effect of certain organic substances on plant growth have been continued, and progress has been made by Miss Adam with the study of the effect of potassic manuring on the anatomical structure of a grass (*Dactylis glomerata*).

At the present time eleven of the laboratory staff and research

workers are on active service, but their places are gradually being temporarily filled by volunteer workers.

The following papers have been published during the year :—

I. "*On the action of certain compounds of Zinc, Arsenic, and Boron on the Growth of Plants.*" WINIFRED E. BRENCHLEY. Annals of Botany, 1914. **28**, 283—301.

Experiments made in water cultures with certain compounds of zinc, arsenic, and boron go to uphold the conclusions arrived at four years ago with compounds of copper and manganese, *i.e.*, that very small quantities of some inorganic poisons stimulate the growth of certain species, but this action is by no means universal. With some poisons the stimulative action is evident, with others it has not been observed; also, a poison that increases growth in one species does not necessarily do so in another, however small a quantity of the reagent that may be applied. A summary of the conclusions arrived at is as follows :—

(1) Zinc sulphate in high concentration is very toxic to barley and peas, and no evidence of stimulation has been obtained with any strength of the poison down to a lower limit of 1/200,000,000.

(2) Arsenious acid is more toxic in its action on peas and barley than is arsenic acid, peas being particularly susceptible. This distinction holds good for sodium arsenate and sodium arsenite, though in a less degree. Again no stimulation is evident with the smallest quantities so far tested.

(3) Boric acid is less poisonous than zinc sulphate or arsenic compounds, especially with peas. Barley shows stimulation to the eye with some of the weaker strengths of poison, but this is not borne out by the dry weights. Peas, on the other hand, are definitely stimulated with relatively high concentrations of boric acid. The action of the greater strengths of the poison is well marked in the leaves, which tend to become brown, and to die in a characteristic manner.

II. "*Mapping as an Ecological Instrument.*" WINIFRED E. BRENCHLEY. Transactions of the Norfolk and Norwich Naturalists' Society, 1914. **9**, 723—733.

The progress of ecological science during the last few years has necessitated the elaboration of special methods of representing and correlating the available facts, one of the most useful of such methods being that of the map, which may now be regarded as a graphical representation of facts from which other facts and hypotheses may be deduced and upon which theories established on a firm basis can be built. A description is given of the various applications of mapping in general use, illustrated by reference to ecological surveys at Erquy (Brittany), and Blakeney Point (Norfolk). The general field map, blocked-in map, grid, transect, and quadrat are discussed and illustrated.

Some of the methods here described are being applied, with the necessary modifications, to field investigations at Rothamsted.

III. "*Partial Sterilisation of Soil by Volatile and Non-volatile Antiseptics.*" WALTER BUDDIN. Journal of Agricultural Science, 1914. **6**, 417—451.

Nearly all the antiseptics used cause increases in bacterial numbers after treatment as Hiltner has already pointed out, and they also mostly produce an initial increase in the amount of ammonia. Here, however, the uniformity ceases, and closer examination shows that two very distinct classes of antiseptics exist—

(1) those which are completely volatile and disappear entirely from the soil once their work is done;

(2) those which remain in the soil for a considerable period or else leave decomposition products and so exert a prolonged action on the bacterial flora and on the plant.

1.—The easily volatile antiseptics are all similar in their action but differ as regards their potency. When a particular strength is reached all the usual partial sterilisation effects observed by Russell and Hutchinson show up together: an initial depression in the numbers of bacteria, the killing of all protozoa, except a few flagellates, the killing of nitrifying organisms, and a small initial production of ammonia; followed later by a large sustained increase in bacterial numbers and in the rate of production of ammonia. The methods used for the examination of the soils did not disclose any substantial difference in result with any higher dose once partial sterilisation had occurred. On the other hand the weakest doses have no effect on the numbers of bacteria occurring in the soil, nor on the rate of production of ammonia and nitrate, and as far as can be judged from the ordinary one per cent. hay infusion culture method, no appreciable action on the protozoa.

The investigation included a group of compounds so mild that they can hardly be considered as antiseptics—the open chain hydrocarbons. These give an initial depression in bacterial numbers and a very distinct increase in the initial ammonia content, but nitrifying organisms are not killed nor are the larger protozoa suppressed. There is no distinct and permanent increase in the numbers of bacteria: there is, however, a marked increase in nitrate production. A similar but weaker action occurs after merely spreading out the soil in a thin layer for 24 hours so that it dries down on the average to about five per cent. water. In this case there is after moistening a similar increased rate of production of nitrate over that in the soil which has been kept in a moist state after being bottled fairly fresh from the field, although there is no noticeable effect on the numbers of bacteria. The decreased action is indicated by the absence of marked initial effects.

2.—The non-volatile antiseptics all produce a permanent depression in bacterial numbers with the highest doses. The more potent such as quinone and hydroquinone show an initial depression in numbers of bacteria developing on gelatine plates even with the weakest dose used (approximately 0·05 per cent.), while the less potent show no initial effects with such strengths excepting the liberation of a small amount of ammonia. With all the antiseptics the dose which is sufficient to produce the full initial depression in numbers also kills the larger protozoa and checks the action of nitrifying organisms. The traces of substance left behind in the

soil exert a very distinct action on the bacterial flora. The usual result is to produce at varying periods after treatment an enormous rise in the number of certain special organisms. This is seen not only in cases where the substance is known to be attackable by certain bacteria, *e.g.*, alcohol and phenol, but in others such as quinone, where such action was not expected. The new flora is not the normal soil flora, although with the very mildly acting antiseptics the old flora may persist in approximately its original complexity but certainly in no greater numbers. The predominant part of the new flora is very much simpler than that remaining after treatment with the easily volatile but potent antiseptics. The colonies are all very slowly growing and consist of only two or three species of bacteria. Determinations of the nitrogen present in the soil as ammonia and nitrate show that the new flora does not produce ammonia. When the abnormally high numbers fall off the condition finally attained depends on the intensity of the initial action: phenol and cresol in weak doses leave a flora which is similar in character to that arising after normal partial sterilisation and produces more ammonia than that of the untreated soil. None of these non-volatile antiseptics, however, leads to such a marked increase in the amount of ammonia and nitrate present after an incubation period as do the volatile antiseptics.

The curves obtained for the numbers of bacteria present after the treatment of the soil with non-volatile antiseptics are remarkably similar to those obtained by Hutchinson and MacLennan with Woburn soil treated with various doses of quicklime. The increased numbers are attributed to an increased supply of food: in these experiments it is difficult to avoid the conclusion that the bacteria are actually feeding on the antiseptics.

The alcohols proved curiously ineffective: formaldehyde also was less potent than was anticipated, behaving in weak doses very much like the open chain hydrocarbons.

IV. "*The increased Nitrate Content of a Soil subjected to Temporary Drying in the Laboratory.*" WALTER BUDDIN. Journal of Agricultural Science, 1914. **6**, 452—455.

A remarkable effect of drying a soil was observed in the foregoing experiments. Soils spread out to dry were found on moistening to have undergone practically no change in bacterial numbers or in nitrate content and to resemble in every point tested similar soils that had remained moist. But at the end of a month it was found that the nitrates had increased to a considerably greater extent in the soil that had been dried although there was no difference in bacterial numbers. The effect closely resembles that of treatment with volatile mild antiseptics.

V. "*Methods of Estimating Carbohydrates.*" II. "*The Estimation of Starch in Plant Material.*" W. A. DAVIS and A. J. DAISH. Journal of Agricultural Science, 1914. **6**, 152—168.

A careful study of the existing methods of estimating starch in plant material has shown that they are unreliable and a new process has been worked out which gives more accurate results.

The Sachsse method, based on the hydrolysis of the starch with dilute acid, fails because the presence of pentosans falsifies the results by giving rise to reducing sugars (pentoses) which count as dextrose, and also because actual destruction of dextrose occurs during the prolonged heating with dilute acid.

O'Sullivan's method, which is sufficiently accurate when pure starch is employed, gives low results in the case of plant material, owing to a loss of dextrin during purification of the solution after the conversion with diastase, this purification being always necessary to remove tannins, proteins, etc., from the plant material.

The method now proposed is based on the fact that taka-diastase in a few hours at 38° converts starch quantitatively into a mixture of two sugars only, maltose and dextrose; no loss of these sugars is to be feared during the ordinary basic lead acetate process of purification.

The details are as follows:—The plant material immediately after picking is dropped into a large volume of 95 per cent. alcohol containing 1 per cent. by volume of 0·880 ammonia. This destroys the plant enzymes and prevents subsequent changes in the carbohydrates. The material is then extracted for 18 to 24 hours with boiling alcohol in a special large form of Soxhlet extractor, so as to remove completely the sugars and other soluble substances. It is then freed from alcohol by pressure and the press-cake is broken up, dried in a steam oven for 18 hours, rapidly ground in a small mill and bottled for analysis.

Ten grams (or a suitable proportion) is dried to constant weight at 100-110° in vacuo over phosphorus pentoxide and the results of the analysis returned on the vacuum-dried weight. To estimate starch, the dry material (previously extracted with water, if necessary, to remove gums, amylans, etc.) is gelatinised with 200 c.c. of water in a beaker flask heated for ½ hour in a water bath at 100°, the mixture is cooled to 38°, 0·1 gram of taka-diastase and 2 c.c. of toluene added, and the mixture left 24 hours for conversion to take place; it is then heated in boiling water to destroy the diastase and the clear solution filtered through a fluted filter paper into a 500 c.c. measuring flask; the leaf residue is thoroughly washed several times by decantation until about 475 c.c. of solution is obtained. The necessary quantity of basic lead acetate solution (generally 5 to 25 c.c.) is then added to precipitate the tannins, etc., avoiding as far as possible any great excess of lead; tests should be made after each small addition so as to ascertain when precipitation is complete. When this is the case, the volume is made up to 500 c.c. at 15° and filtered; 100 c.c. of the filtrate are placed in a 110 c.c. flask, the slight excess for lead precipitated by adding solid sodium carbonate and the volume adjusted to 110 c.c. 50 c.c. of the filtrate from the lead carbonate are used to measure the reducing power and another portion polarised in a 400 mm. tube. From the values so obtained the quantity of maltose and dextrose present can be calculated and the percentage of starch obtained. The values obtained by Brown, Morris, and Millar for the reducing power of dextrose and maltose are used as a basis of calculation.

Several examples are given of the application of this method to plant material, and the necessity is emphasised of removing optically active substances soluble in water, such as gums. Special care is

also necessary in taking the sample for analysis, as the material which falls to the bottom of the stock bottle is often far richer in starch than the lighter fibrous material that rises to the top.

VI. "*Some Notes on the Chemistry of Starch and its Tranformations.*" W. A. DAVIS. Journal of the Society of Dyers and Colourists, July, 1914.

It is shown that taka-diastase, the enzyme of *Aspergillus Oryzae* converts starch first into dextrins, then into maltose and finally into dextrose. After a few hours all the dextrin has disappeared and the product consists of maltose and dextrose only; the amount of dextrose gradually increases with the time. It is considered that taka-diastase contains maltase as well as the ordinary enzymes of malt diastase and that this converts the maltose into dextrose. No evidence could be obtained that taka-diastase converts starch directly into dextrose.

The departure of the hydrolysis from a simple logarithmic curve, is ascribed to the occurrence of several successive stages.

VII. "*The Action of Cold Concentrated Hydrocloric Acid on Starch and Maltose.*" A. J. DAISH. Transactions of the Chemical Society, 1914. **105**, 2053.

The action of cold fuming hydrochloric acid (D^{15} 1·210) on starch appears to be essentially the same as that brought about by taka-diastase. The first stages—the formation of soluble starch, dextrose, and maltose—are, however, passed through very rapidly and after 135 minutes 86 per cent. of the theoretical quantity of dextrose has been formed. The action is apparently limited by the rate of hydrolysis of the maltose, since this is hydrolysed to dextrose not much more rapidly than starch itself.

When dextrose is dissolved in ordinary concentrated or fuming hydrochloric acid a certain amount of synthetic action always occurs, even when only 1 per cent. of the sugar is present. This fact, and the destruction of some of the dextrose, makes it impracticable to utilise cold fuming hydrochloric acid in the accurate estimation of starch or cellulose.

VIII. "*The Velocity of Hydrolysis of Starch and Maltose by Cold Concentrated and Fuming Hydrochloric Acid.* A. J. DAISH. Transactions of the Chemical Society, 1914. **105**, 2065.

When fuming hydrochloric acid acts on maltose at the ordinary temperature the velocity coefficient is practically constant throughout the change; the action is unimolecular. But when either the fuming or ordinary concentrated acid acts on starch or soluble starch the velocity coefficient is not constant but rises continuously throughout the change; the departure from the ordinary logarithmic law is ascribed to the occurrence of successive stages. The transformation of cellulose by fuming hydrochloric acid is an extreme instance of an action occurring in successive stages, and the velocity co-efficient also shows considerable variation at different periods.

IX. "*Methods of Estimation of Carbohydrates III. The Cupric Reducing Power of the Pentoses—Xylose and Arabinose.*" A. J. DAISH. Journal of Agricultural Science, 1914. **6**, 255—262.

In the scheme of analysis of plant extracts outlined in last year's report (1913, pp. 12-14) allowance must be made for the pentoses present; it therefore became necessary to ascertain the exact value of the cupric reducing power under the standard conditions of Brown, Morris, and Millar. Pure specimens of the xylose and arabinose were therefore prepared and the reducing power at different degrees of concentration accurately determined. The results are given in tables and curves, enabling one to read off directly the weight of pentose corresponding to different weights of cupric oxide. The specific reducing power of the pentoses differs only very slightly from that of dextrose.

X. "*The Estimation of Carbohydrates IV. The Presence of Free Pentoses in Plant Extracts and the Influence of other Sugars on their Estimation.*" W. A. DAVIS and G. C. SAWYER. Journal of Agricultural Science, 1914. **6**, 406—412.

The existence of free pentoses in plants has not hitherto been recognised. Evidence is adduced to show that they are usually present in the alcoholic extracts of leaves of turnips, mangolds, potatoes and other plants. This also explains their accumulation in the "vinasses" of distilleries employing the molasses of the beet sugar industry.

It is shown that the pentoses may be estimated quantitatively with a fair degree of accuracy by the ordinary distillation process or from the reducing power of the purified liquor after other sugars have been fermented away with yeast.

When the amounts of pentoses are small, relative to the other sugars, it is advisable, as suggested by Kluyver, to ferment away these sugars completely before applying Kröber's process.

XI. "*The Hydrolysis of Maltose by Hydrochloric Acid under the Herzfeld Conditions of Inversion.*" W. A. DAVIS. Journal of Agricultural Science, 1914. **6**, 413—416.

It is shown that maltose undergoes slight hydrolysis (about 2 per cent. when 1 per cent. solutions of maltose are employed) when heated with hydrochloric acid under the Herzfeld conditions of inverting cane sugar. It is preferable, therefore, to adopt 10 per cent. citric acid as suggested in last year's report, as this acid causes no hydrolysis of maltose under the conditions prescribed.

XII. "*Estimation of the Surface of Soils.*" J. A. HANLEY. Journal of Agricultural Science, 1914. **6**, 58—62.

The method of König, Hasenbäumer, and Hassler for estimating soil colloids by means of dyes was considerably modified.

Methyl violet was used, as this colour undergoes only a slight change even after prolonged contact with the soil; but it was shown to be useless to employ dye solutions of the same strength for soils of the same type, *e.g.*, for sands, 1 gram; for loams, 2 grams; for clays, 3 grams of dye per litre.

The reaction is a typical absorption and the quantity of dye taken up depends on the strength of solution used, an equilibrium setting up between dyed soil and dye solution. For comparing surfaces of soils it is therefore necessary to estimate the dye absorbed when the *dyed* soils are in contact with supernatant dye solutions of the same strength. A series of dye solutions has therefore to be used for each soil and the appropriate concentration picked out by trial.

XIII. "*The Humus of Acid and Alkaline Peats.*" J. A. Hanley. Journal of Agricultural Science, 1914. **6**, 63—76.

Experiments were made to determine whether acidity or alkalinity of peats depends on the presence of acid or alkaline humus.

In every case part of the organic matter could be extracted without previous treatment with acid, and when the soils were arranged in order of the ratio of humus obtained without, to humus obtained with, previous acid treatment, alkaline fen peats, some of which contained carbonate, were found high in this "acidity" list.

Five typical peats were examined in more detail.

The humus determinations were repeated with ammonia and with caustic soda, and the nitrogen in the extracts was estimated, but the results, which were probably affected by the solubility of neutral organic matter, showed less connection with the other characteristics of the peats than those obtained by studying the inversion of sucrose.

Acid peats have a greater power of inverting sucrose than neutral peats. In order to eliminate the effect of varying organic matter content it was found necessary to compare the ratios of inversion after, to inversion before, treatment of the soil with dilute hydrochloric acid. For acid peats the ratio approached 1, for normal peats it was very low; in the case of a Cambridge Fen peat, 0·062.

XIV. "*The Relative Effect of Lime as Oxide and Carbonate on certain Soils.*" H. B. Hutchinson and K. MacLennan. Journal of Agricultural Science, 1914. **6**, 302—322.

Further evidence is adduced to show that caustic lime acts as a partial sterilising agent, as pointed out in the previous paper dealt with in last year's Report. The amount of lime required for this purpose is found to vary with different soils. Each soil absorbs a certain amount of lime; only the excess over and above this absorbed quantity produces any sterilising effect. In addition, the lime liberates a certain amount of ammonia. The available nitrogen in the soil as found by pot experiments was found to be comparable with the amounts of ammonia and nitrate produced in the laboratory experiments.

Chalk, on the other hand, has no partial sterilising action.

XV. "*The Determination of Soil Carbonates.*" H. B. Hutchinson and K. MacLennan. Journal of Agricultural Science, 1914. **6**, 323—327.

A method is described for rapidly estimating the carbonates in soil. The apparatus consists of two round bottomed flasks of 100

and 1,000 c.c. capacity respectively, connected by a glass tube and each provided with tap funnels. The smaller flask contains the soil, the latter is to hold the alkali for absorbing the CO_2. The apparatus is partially evacuated (a water pump suffices for this purpose), the alkali is run into the larger and the acid into the smaller flask. After the first action is over air is allowed to bubble slowly through the mixture of soil and acid in order to carry the remaining CO_2 into the larger flask. The CO_2 is then determined by titration.

XVI. "*The Determination of the Lime Requirements of Soils.*" H. B. HUTCHINSON and K. MACLENNAN. Chemical News, 1914. **110**, 61.

A new method is proposed for the determination of the lime requirements of the soil. 10 to 20 grams of the soil are placed in a bottle of 500-1,000 c.c. capacity together with 200-300 c.c. of approximately N/50 solution of calcium carbonate, and the air in the bottle is displaced by a current of carbon dioxide in order to insure against possible precipitation of calcium carbonate during the period of the determination. The bottle is then placed in a shaking machine for three hours, after which time the solution is filtered and an aliquot portion of the filtrate is titrated against N/10 acid, using methyl orange as indicator. The difference in strength of this filtrate and that of the initial solution represents the amount of calcium carbonate absorbed, each cubic centimetre of N/10 acid being equal to 5 mgrms. calcium carbonate. The method has been found to provide a useful index of the lack of base or "sourness" of the soil.

XVII. "*The Evaporation of Water from Soil.*" BERNARD A. KEEN. Journal of Agricultural Science, 1914. **6**, 456—475.

The evaporation of water from sand, silt, china clay, and ignited soil is a relatively simple phenomenon which can readily be explained by the known laws of evaporation and diffusion. The evaporation from soil is more complex, something being present which operates in making the relation between the soil and the soil water of a different and closer nature than in the case of sand, etc. The effect is not due to the soluble humus, for the removal of this material from the soil does not appreciably affect the phenomena of evaporation. Any possible effect of the insoluble organic matter is largely eliminated by the consideration that *ignited* sand or silt behaves like the *unignited* material.

But when the colloidal properties of the clay are destroyed by ignition, the evaporation curve is completely altered, and becomes identical with that given by sand or silt. Again, evaporation from china clay, which shows very feeble colloidal properties, is of the same character as that from sand. We may infer then, that the colloidal properties of the clay fraction are partly, if not mainly, responsible for the characteristic shape of the evaporation curve from soil.

Further information on the process of evaporation has been obtained by a mathematical examination of the rate curve for soil. Two factors have been distinguished, which operate over practically the whole range of water content dealt with in these experiments.

In the first place the initial proportionality between water content and time observed with sand is not seen with soil, the curve being more exponential in character. This indicates that the relationship of water to soil is quite different from its relationship to sand, a circumstance which has been traced as already stated to the colloids. This relationship has at present only been expressed empirically but it is probably connected with the relation between vapour pressure and moisture content. But there is clearly something else at work for the curve is not of a simple exponential type. It is necessary to allow for another factor: the effect on the rate of evaporation of the decreasing water surface in the soil, the surface obviously diminishing in area as evaporation continues.

The equation finally developed is:—

$$A\frac{dw}{dt}=\sqrt[3]{\left(\frac{ws}{100}+1\right)}\,[2{\cdot}303\log_{10}(w+K)-\log_e K],$$

where $\frac{dw}{dt}$ = rate of evaporation.

w = percentage of water present by weight.

s = specific gravity of the soil.

A and K = constants.

XVIII. "*Some Notes on Soil Protozoa.*" C. H. Martin and K. R. Lewin. Philosophical Transactions, 1914. **205 B**, 77—94.

The authors show that the view current among zoologists limiting the range of free living protozoa to ponds, streams, the sea, etc., is not justified by the observations of the older investigators. A method is described by which it is easy to demonstrate in field and garden soils the presence of free living protozoa in a trophic state: it is as follows:—A small quantity of the soil is added to an equal quantity of a saturated aqueous solution of picric acid; the mixture is then stirred very thoroughly, so that the protozoa which are situated on the liquid films between the soil particles are freed. The mixture is then allowed to stand for 12—24 hours, and a scum gradually rises to the surface which contains a proportion of the bacteria and protozoa of the soil. Cover slip preparations are made by floating cover slips on the surface of the mixture, then transferred to corrosive sublimate solution or 70 per cent. alcohol, stained and mounted in the ordinary way.

At least eight organisms, some of them new, were discovered in a trophic state in a "sick" cucumber border. The thecamoebae were probably present in considerable numbers, as also were the amoebae, which contained large numbers of ingested bacteria. Neither flagellates nor ciliates were observed in any quantity in the trophic state. An organism, *Vahlkampfia soli*, appeared to be the dominant form during August and is described in some detail as it differs in certain points from *Amoeba limax*. It is very active and has a flagellate stage: in nuclear division it shows the phenomena of promitosis. A second organism, *Amoeba cucumis*, is also described; this is very sluggish and has characteristic pseudopodia.

An outdoor seedling bed was found to contain a smaller number of protozoa but in larger variety: a relationship very similar to that

observed on the Rothamsted grass plots, where the unmanured plot carries the largest number of species but a low crop, whilst the heavily manured plots carry a smaller number of species. One organism was described in some detail, *Amoeba gobanniensis*, which is of interest because it is closely allied to *Amoeba cucumis*. A *Chlamydophrys* was also found, different from the forms previously described.

NOTE.—In a later paper, which was almost ready for the Press when the authors were called up for military service, Messrs. Lewin and Martin describe another method by which protozoa in the trophic form were picked out of the soil alive. A glass tube 1½ inches in diameter and about 2 feet long is closed at the lower end with a rubber bung through which passes a glass tube drawn out to a jet whereby a current of air can be blown through. The tube having been clamped upright, a newly made suspension of the soil in water is poured in until the water level nearly reaches the top. Three hooks are hung round the rim of the tube so as to furnish a support for the cover slip which is smeared with agar jelly and placed about ¼ inch above the water level. Air is now blown through the jet so as to produce a stream of fairly small bubbles rising through the suspension and breaking on the cover slip. After about 30 seconds the air stream is stopped and the cover slip lifted off and examined under a microscope.

XIX. "*A Preliminary Communication on Three new Proteomyxan Rhizopods from Soil.*" T. GOODEY. "Archiv für Protistenkunde," 1914. **35**, 80—102.

The organisms described in this paper were obtained in cultures of soil on a nutrient agar medium and the soils which yielded them were all of a rich character. They were first obtained from a cucumber house at Harpenden, and from a vinery in Hampshire; later on they were obtained from rich garden soils taken in Edgbaston, Birmingham, and Great Barr, Staffordshire. This shows that they are widely distributed. They are large amoeboid forms and are new to science.

Leptomyxa reticulata nov. gen. et. nov. spec. is the largest of the three and measures from 40 μ to 1 m.m. in greatest breadth. The protoplast spreads out into a thin sheet branching and anastomosing; pseudopodia often filose and delicate; contractile vacuoles numerous and minute, multinucleate, each nucleus small and possessing a comparitively large karyosome. Encystation into double-walled cysts; excystation of original organism.

Leptomyxa flabellata nov. spec. The protoplast is naked and spreads out into a thin sheet frequently resembling a fan in outline, measuring from 60 μ to 150 μ in breadth. The pseudopodia are filose but do not anastomose; contractile vacuoles numerous and minute. Multinucleate, possessing from 1 to 14 nuclei much larger than those of *L. Reticulata* each having a large karyosome. Encystation into double-walled cysts, the ectocyst showing well defined prominences; excystation of original organism.

Gephyramoeba delicatula nov. gen. et. nov. spec. The protoplast is naked and stretches out into long narrow arms

measuring from 60 μ to 250 μ from tip to tip. Contractile vacuoles numerous and minute. Encystation into single-walled cysts; excystation of original organism.

All three forms feed on bacteria and small amoebae and flagellates.

XX. "*The Estimation of Phosphates in Soil Extracts.*" J. A. PRESCOTT. Journal of Agricultural Science, 1914. **6**, 111—120.

The volumetric method originally proposed by Pemberton for the determination of phosphates has been investigated, and the conditions for obtaining accurate results with soil extracts have been worked out.

The following is the method finally adopted :—

REAGENTS. (1) Ammonium nitrate: 500 gms. to 1 litre of water.

(2) Ammonium molybdate: 150 gms. molybdate dissolved in 1,000 c.c. of water and poured into 1,000 c.c. of nitric acid (S.G. 1.2).

(3) 2 per cent. sodium nitrate.

PREPARATION OF SOIL EXTRACTS. A volume of the extract containing 5 to 10 m.g. of P_2O_5 is evaporated to dryness, ignited for 15 minutes at dull red heat, and where much silica is present, roasted for 2 hours at 140°C to render the silica insoluble. The residue is extracted with 50 c.c. of 10 per cent. sulphuric acid by digestion for half an hour on a sand bath; the extract is diluted and filtered.

PRECIPITATION OF THE PHOSPHO-MOLYBDATE. To the above extract, 25 c.c. of the ammonium nitrate solution is added and the mixture brought to 55°C. 25 c.c. of the molybdate solution, previously brought to the same temperature, is then added and the mixture stirred, allowed to cool, and filtered after 2 hours. The precipitate is washed free from acid with 2 per cent. sodium nitrate solution, dissolved in standard alkali and titrated back using phenol phthalein as indicator. The factor recommended is 1 c.c. of $\frac{N}{10}$ alkali = ·0003004 gms. P_2O_5.

XXI. "*The Reaction between Dilute Acid Solvents and Soil Phosphates.*" J. A. PRESCOTT. Proc. Chem. Society, 1914. **30**, 123.

A preliminary note showing that the reaction is more readily interpreted as a colloidal absorption phenomenon than as a simple chemical reaction (*see p.* 9).

XXII. "*The Nature and Amount of the Fluctuations in Nitrate Contents of Arable Soils.*" E. J. RUSSELL. Journal of Agricultural Science, 1914. **6**, 18—57.

The amount of nitrate in the soil of arable land fluctuates regularly, but in these experiments it rarely exceeded the following values :—

	Per million	Per cent.	Lbs. per Acre, 0—18 ins.
Sand ...	6	·0006	28
Loam ...	23	·0023	115
(excepting on heavily dunged land, when it rose to 37 parts per million).			
Clay ...	14	·0014	60

In almost all the soils examined the accumulation of nitrate took place most rapidly in late spring or early summer. After this there was usually little if any gain, and frequently a loss. In the hot dry autumn of 1911, however, and again in 1913, the accumulation continued in some of the soils right on till September.

During the winter loss of nitrate took place. This was more marked in the wet winter of 1911—1912 than in the drier winter of 1908—1909.

The fluctuations in nitrate content are more marked on loams than on clays or sands. Clays lose less of their nitrates in winter, but, on the other hand, they accumulate smaller amounts in June and July. Sands lose much of their nitrates in winter and do not accumulate very large amounts in summer. It appears that the main loss in winter is due to leaching and not to denitrification.

On comparing the nitrate content of cropped and fallow land it is found that during late summer and early autumn the fallow land is the richer, even after allowing for the nitrate taken up by the crop. The question arises, whether the growth of a crop exerts any depressing effect on the rate of nitrate production in the soil. This is under further investigation.

The rapid rise in nitrate content in spring does not usually set in immediately the warm weather begins; there is a longer or shorter lag. There are indications of greater bacterial activity in early summer than later on, a phenomenon readily explicable on our view that the soil population is complex and includes organisms which are detrimental to the activity of bacteria, but which are, on the whole, more readily put out of action.

The supply of nitrate to the plant is known to be a factor of prime importance in plant growth. Similarly it is found that the factors which determine the accumulation of nitrates in the soil also play a great part in determining the amount of crop production. Thus heavy winter rainfall, which washes out nitrates, tends to reduce crop growth; on the other hand, hot dry summers, succeeded by dry winters, are shown to be favourable to nitrate accumulation, and therefore to crop growth.

XXIII. "*The Effect of Climate and Weather on the Soil.*" E. J. RUSSELL. Journal of the Royal Agricultural Society, 1914. **74**, 1—21.

Climate is shown to play a considerable part in determining the character of a soil, affecting not only the mineral particles, but also the nature and amount of the organic matter. Where definite climatic zones exist they are usually found associated with definite soil zones. Instances are quoted from North America and from Russia.

The effects of weather are of more direct interest to the cultivator, and involve the texture of the soil and also the stores of nitrates. Using the data collected in the preceding paper it is shown how a considerable saving may be effected by sowing a green crop at the end of a dry summer or autumn, which shall take up the nitrates and save them from being washed away. When the crop is ploughed in or folded, the nitrogen is returned to the soil in a form in which it is not readily lost.

SHORT TECHNICAL PAPERS.

During the year a series of short papers has been published, dealing with technical problems in the light of investigations going on in the field, the pot culture house and the laboratory.

I. "*On the Loss in a Stack of Unthreshed Corn.*" E. J. RUSSELL. Journal of the Board of Agriculture, 1914. **21**, 300—304.

This paper records the history of two stacks which, instead of being threshed soon after harvest, were left till the following October. In both cases the loss was found to be serious—in one there was a considerable loss of grain, in the other the total grain did not greatly decrease, but much was damaged and came out as tail corn. It is shown that a man who kept his wheat unthreshed till May has in normal years a chance of obtaining 10 per cent. higher price for it, but he runs the risk of incurring a far greater loss. The conclusion is that under ordinary circumstances wheat should be threshed out as soon after harvest as possible.

II. "*Ashes of Hedge Clippings and Trimmings as a Source of Potash.* E. J. RUSSELL. Journal of the Board of Agriculture, 1914. **21**, 694—697.

Hedge trimmings were found to contain some 10 per cent. of potash (K_2O) and thus to be nearly as rich as kainit; the trimmings of a 20-acre field yielded ash equivalent to nearly 2 cwt. of kainit. Since the potash occurs as the highly soluble carbonate, serious loss arises when the bonfire ash is exposed to rain; in these experiments it amounted to one half. It was not found difficult, however, to improvise temporary shelters. The ash mixes well with super-phosphate and can be applied in this way.

III. "*The Prevention of Loss from Manure Heaps in Winter and Early Spring.*" E. J. RUSSELL and E. H. RICHARDS. Journal of the Board of Agriculture, 1914. **21**, 800—807.

Manure heaps were set up under various conditions of storage indicated by the laboratory experiments, and it was found that serious loss was occasioned when rain washed into the heap, even though no visible drainage took place. The cause is discussed on p. 8. The old view that loss is due to volatilisation of ammonia cannot be regarded as complete, and it thus becomes possible to explain the failure of some of the conservation methods that have been suggested on this hypothesis. Rain now appears to be the great enemy, causing loss even when nothing is draining from the heap and, of course, more serious losses when visible leaching occurs. Considerable saving was effected by sheltering the heap, and the loss was reduced to very small proportions by a combination of sheltering and compacting.

IV. "*Third Report on the Partial Sterilisation of Soils for Glasshouse Work.*" E. J. RUSSELL. Journal of the Board of Agriculture, 1914. **21**, 97—116.

This paper contains an account of the large scale trials that

have been made in glasshouses in the Lea Valley district. High pressure steam, low pressure steam, and baking were all tried, and each found to possess some advantages. One of the low pressure steam methods was found to work very easily for heating soils *in situ*; a high pressure steam method was found to work well in combination with trenching.

Methods are described for dealing with rankness of growth, perhaps the chief danger arising out of the partial sterilisation of soils.

This work is now being transferred to the new Experiment Station which has been opened in the Lea Valley.

V. "*The Work of the Rothamsted Experiment Station.*" E. J. Russell. Journal of the Board of Agriculture, 1914. **21.**

A description of some of the recent work of the Station in its bearings on technical problems of present-day interest.

VI. "*The Effect of One Growing Crop on Another.*" E. J Russell. Fourteenth Report of the Woburn Experimental Fruit Farm.

VII. "*Results of Experiments with Chrysanthemums on Partially Sterilised Soils during 1913.*" W. Buddin. Transactions of the National Chrysanthemum Society, 1913. **21—24.**

A continuation on a larger scale of the experiments dealt with last year. The earlier results were in the main confirmed. When equal numbers of blooms were carried per plant those obtained from the steamed compost were larger and firmer than those from the untreated compost. When, however, the plants on untreated carried fewer blooms they were of as good quality as those on the steamed compost. The earlier blooming on the steamed compost was less marked than in last year's experiments.

MONOGRAPHS.

It is proposed to bring out a series of monographs in which the members of the Staff will discuss the particular problems they have been investigating, as soon as sufficient material has accumulated to render such a course desirable. Two have already been written :—

"*Soil Conditions and Plant Growth.*" 2nd Edition, revised and enlarged. E. J. Russell. Longmans & Co., 5/- net.

"*Inorganic Plant Poisons.*" Winifred E. Brenchley. Cambridge University Press, 5/- net.

THE EXPERIMENTAL PLOTS AND FIELDS.

1914 like 1913 was characterised by a long dry summer, but it was much more sunny, indeed over the whole season, April to September inclusive, there were 1,211 hours of sunshine against only 899 in 1913. The last four months of 1913 had been drier than usual so that the work was well forward: January also was relatively dry and favourable for work in the fields, while the frosts and the dry weather of December helped materially in getting the soil into good condition. The winter wheat started well, the general mildness of the winter being favourable to growth. February and March were very wet, 7·55 inches of rain falling against an average of 3·73 so that the work on the land was brought to a standstill. Then followed a spell of dry sunny days with a cold N.E. wind, which greatly checked winter corn and grass and was not very favourable for the getting of a tilth, in consequence the barley came up somewhat unevenly. May was a bad month for growth: it was dry, cold with N.E. and N.W. winds and there were several frosts. Warmer weather set in in June and a good shower of rain helped both mangolds and potatoes considerably, but it came too late to save the hay, which was very short. The drought continued so long that Brussels sprouts had to be watered in.

Harvest weather was good, and ploughing for winter crops was kept going notwithstanding the persistence of the drought. The winter corn had ripened well but the barley was late and its uneven ripening caused the harvest to be prolonged.

Mangolds were seriously affected by the dry summer, the yield on Barnfield being brought down to almost exactly one half the average. Hay also was badly affected and the only plots in the Park approaching normal yields were those receiving nitrate of soda or sulphate of ammonia. Clover hay grown in the Rotation experiment on Agdell Field also gave low yields. The Broadbalk wheat was again poor, the yields being almost identical with those obtained in 1913, but for this the season is only partly responsible. Continuous wheat growing allows very few opportunities of cleaning the land, and weeds have obtained so strong a hold on this field that hoeing and hand-weeding are insufficient to keep them down, and indeed the processes finally injure the crops more than the weeds. The committee therefore decided to fallow the west or top half of the field in 1914, and the east or bottom half in 1915. Only once before since the experiment began in 1843 has there been a fallow, and that was in 1903-4 and 1904-5, when however, the operation was carried out by dividing each plot into a north and south half and fallowing one in 1903-4 and the other in 1904-5. The method did not prove very successful by reason of the narrowness of the strips.

On the ordinary farm land Long Hoos Field yielded 39 bushels of wheat per acre, but Great Knott Field, which had been badly attacked by birds, only yielded 24 bushels per acre.

The Hoos Field barley, grown continuously on the same land, was somewhat below the average and very considerably below the extraordinarily high yields of 1913 which followed on the fallow of 1912. Higher yields were obtained in the adjoining Little Hoos Field where barley is grown in rotation; perhaps the most interesting

feature here was that ordinary dung gave almost the same results as cake fed dung, no advantage accruing from the cake.

THE NEW FARM.

Up till recently the Rothamsted Experimental Station had only five fields, and as these were fully occupied with the classical experiments no land was available for new work. In 1911, however, an additional 230 acres were taken on a long lease and were gradually got into order; they are farmed largely without stock, manures being purchased and everything sold off, this method having certain advantages when experiments are to be undertaken. There being no buildings available, some were erected—stables, stalls for six bullocks, a covered manure yard, and the usual chaffing room, granary, store for artificial fertilisers, etc. In addition, a large Dutch barn has been built, with stout wooden posts set in concrete and affording 8,550 cubic yards capacity, the cost of which was only £127.

Much of this land is farmed in the ordinary way, but from time to time additional areas are brought into experiment; this is done in a definite systematic manner to test some method or principle devised in the laboratory. The usual course is that the laboratory investigations clear up some point in soil fertility or in plant nutrition, and suggest some way in which the growth of the plant might be increased. The method is carefully tested by pot experiments carried out under carefully controlled conditions in the pot culture house, and the laboratory experiments are revised in the light of the results obtained. Thus the *principle* of the method is established. It does not follow, however, that the method will work in the field: the weather, the subsoil, the difficulties of manipulation and other causes may all operate against it and reduce or nullify its effects. Field experiments are therefore made, first on a small scale, and then if need be on a larger one.

Broadly speaking, there are two ways in which soil fertility investigations may be applied to agriculture: they may lead to increases in crop or they may enable the farmer to obtain the same crop at lower cost. There are limits set by the climate to the possibilities of increasing the crop: but there is no limit to the farmer's desire to lower the cost of production.

Another guiding principle is that so far as possible old methods are utilised and developed instead of seeking to bring out quite new ones. The old methods have many advantages: they are effective or they would not have survived, they can be worked on the farm, and they are capable of improvement.

In laying out new experiments at Rothamsted it is unnecessary to conduct simple manurial trials except with new fertilisers. The old plot experiments admirably demonstrate the properties of the artificial manures and their effects on the crop and the soil: our newer experiments, therefore, start out from the basis thus acquired.

One of them is directed to the study of problems revealed by the periodical surveys of the plots, one of which is now in progress. The manures applied in certain cases contain 80 to 200 lb. of nitrogen, but we only recover some 50 or 60 lb. in the crop and the

remainder is lost. How can we recover more and thus secure a better return for our outlay? Part of the loss cannot yet be explained, and is under investigation in the laboratory, but part is due to the failure of the plant to take up all the food given to it. A proper balancing of the manure enables the difficulty to be got over to some extent; in the following two instances the same amount of nitrogen is given in each case, but in one the manure is well balanced while in the other it is not.

	Broadbalk Wheat		Amount of Nitrate running away in drainage water, per million	Barnfield Mangolds	
	Grain, bushels per acre	Straw, cwt. per acre		Roots, tons per acre	Nitrogen recovered, lb. per acre
Badly balanced manure ...	16·0	14·0	17·8	24·7	134
Well balanced manure ...	26·7	30·8	8.5	29·3	172

Laboratory experiments were made to see if any stimulant could be administered to the crop to get it to utilise the food materials better, and manganese salts appeared to have this effect, but trials in the field have not yet proved successful.

The crops are not abnormally large and the varieties used are capable of better growth; something is clearly standing in the way. Inspection of the soil at once shows that it is too heavy to give the best results; the soil type therefore is one limiting factor.

Now this difficulty is an old one and has long since been met by an old device. Chalk lies below the surface of the land in Hertfordshire and the old practice was to dig down for it and apply it to the land at the rate of 80 or 100 tons per acre. The treatment was effective, but it is costly. More recently economy has been effected by using smaller dressings or by substituting lime, but however the process is modified it has to be adopted in some form or other. Seeing, therefore, that we must have recourse to chalking and liming, a series of laboratory and field experiments was undertaken to see just what the lime and the chalk do in the soil and how much—or rather how little—is needed to effect improvement. These have already been discussed on p. 8. While the laboratory investigations were in progress a field experiment was started. The land was divided into three parts, one receiving, at a cost of £3 6s. 8d. per acre, a dressing of 20 tons of small chalk obtained in the excavation of a sewage filter bed; one was chalked on the old Hertfordshire method by the men who make a speciality of this kind of work, approximately 50 tons being given at a cost of £3 7s. 10d. per acre; and the third was left untreated. This was done during the winter of 1912-13. The effect of the chalk on the physical texture of the soil was manifested in a few months. Cultivation became and has remained easier: the ploughman found his work facilitated, the board running cleaner than on the unchalked land. A considerable proportion of the outlay was recovered in the 1913 crop; in 1914, however, neither oats nor barley showed any benefit.

CULTIVATION EXPERIMENTS.

Another method by which the soil conditions may be improved for the plant is to increase the depth of soil over which the roots may range. There are some very old Rothamsted experiments on the subject. In 1849 the Rev. S. Smith, of Lois Weedon, Northamptonshire, attempted to prove that trenching could profitably be undertaken for wheat cultivation. Trenched plots were therefore laid out for wheat in Hoos Field, the method being to bring up the subsoil and bury the top soil. No increase in crop was observed, however. More recently (1909) the experiment was repeated with fruit trees, the trenching being done on the modern method in which the subsoil is kept below and the top soil kept on top. No evidence could be obtained that trenching had any effect either on the growth of the trees, or on the soil moisture or nitrates. Now trenching is not a farm operation, but it is closely related to subsoiling which is usually considered valuable, and in order to clear up the problem some plots have been laid out to test the effect of subsoiling: this year potatoes were grown on them and showed consistent increases in crop. Mr. F. J. Gurney kindly gave us the implement, which worked very well, breaking up the subsoil with a minimum expenditure of labour.

Another experiment has been started on the methods of sowing wheat after potatoes. When the digger has finished its work in autumn the soil is left in a beautifully fine tilth eminently suitable for the nitrification processes. How can this best be utilised? The field has been divided into five strips: in one the wheat has been drilled shallow, ploughed in, and harrowed; in another it was broadcasted, ploughed in, and harrowed; on the third the wheat was drilled on the surface left by the digger, and put in as deeply as the soil allowed, there being no ploughing or other preparation; the fourth was ploughed and then drilled in the usual way; the fifth was ploughed and broadcasted. The first two strips look the best and lay dry through the heavy December rains of 1914: the third has become badly beaten down by the rain, the fineness of the tilth causing the soil to run together very much, a result that was also obtained last year in similar circumstances: the other two are intermediate.

It is proposed to extend these cultivation experiments, for probably less is known about the cultivation processes than about any other branch of soil treatment. Before designing any proper set of experiments, however, it is necessary to know what cultivation does. A series of laboratory experiments is already in hand to study the air, water and temperature relationships of the soil, which are known to be affected by cultivation, and it hoped to get some information about that remarkably intricate subject, the texture of the soil. When these are more advanced it will become possible to evolve some scheme of tillage experiments to examine such problems as the difference between a "fresh" and "stale" furrow, which are known to be of practical importance, but which have not received the attention they deserve from experimenters, and indeed cannot until they have been more systematically studied.

THE GREEN MANURING EXPERIMENT.

Throughout the Rothamsted experiments a number of observations have shown the marked effect of ploughing-in a green crop or a crop residue as a preparation for a succeeding crop. Every four years the residues of a clover crop after carting the hay are ploughed-in on half of the Agdell Field, and the effect on the succeeding crops in the rotation is recorded. In Hoos Field some leguminous crop has periodically been ploughed-in and a number of grain crops have then been grown, almost always with beneficial results.

The growing scarcity of stable manure renders it imperative that some method should be worked out whereby the farmer can get all the benefit of stable manure in some other way, and green manuring affords an obvious means of doing this. Experiments in the laboratory and pot culture house, however, showed that the growing plant has a complex effect on the soil and on other crops, and that one could not without further trial advocate unrestricted green manuring. For example, it was found that the growing plant apparently depressed nitrification and other bacterial actions in the soil, and that some interval was needed between two crops in order that the bacterial processes might become completed.

Another action is indicated as the result of Mr. Pickering's work at Woburn: one growing crop has an injurious effect on another growing crop apparently through exerting some deleterious influence on the soil. It appears, therefore, that there is another side to the question, and that a growing crop not only takes out certain plant foods (which are automatically returned when the crop is ploughed-in, or can be added as artificial fertilisers), but it may also have other effects. This is while it is actually growing: the residues ploughed-in seem to be wholly beneficial—at any rate no ill-effect has yet been detected in the field, although one (a destruction of nitrate in certain circumstances) has been indicated in the laboratory. So far as our present knowledge goes the best results are only attained when a period of fallow comes after the green manure crop.

Thus green manuring is intimately bound up with fallowing. It was shown in the last Report that fallowing had a very beneficial effect on the crop of barley and further observations to the same effect have been made this year. Winter oats on Sawpit Field taken after a fallow were better than crops fertilised with nitrogenous manures. No green manure or crop residue was ploughed in either for the barley or oats, but this year an experiment was made to find the effect of combined crop residues and fallow on wheat. A four-year-old lucerne ley on Broadbalk Field was broken up, fallowed during the hot weather and sown with wheat in October, 1913. The land had received no manure for some years, but the wheat crop was greater than on any plot receiving artificial manures, and at least as large as that on plot receiving 14 tons of farmyard manure. Even more remarkable, however, was the effect on the weight of the grain. Practically all the wheat on the regular plots with the exception of the unmanured had the same density, viz.: 62·2 lbs. per bushel, this being independent of the amount or nature of the fertiliser used. The wheat after lucerne had a heavier grain, weighing 63·9 lbs. per bushel.

But in regard to fallowing a difficulty at once arises. While the land is lying fallow it is subject to loss of nitrates by leaching; indeed one of the great merits of green manuring is that it puts a crop on the land in autumn when the stock of nitrates is high and the crop takes up the nitrates and holds them safely from the winter rain. A simple way round the difficulty is to have the necessary fallow only during the dry weather, and it so happens that all our experiments were made under these conditions.

It is to clear up these and similar problems that a definite green manuring experiment has been begun. A field is divided into four parts, one of which is farmed with artificials only, one with farmyard manure and artificials, and two with artificials and green manure but no farmyard manure. One of the two last carries leguminous crops and the other non-leguminous crops for the green manure. An eight-year rotation has been drawn up to keep the green-manured land as closely cropped as possible, and to reduce to a minimum all losses by leaching; whether other losses will also be reduced has yet to be determined. The eight-year run should show how far green manuring can be regularly practised under farming conditions, and whether periodical fallows will be necessary.

Meanwhile, in view of the marked benefit just recorded of the fallow coming after the lucerne ley and of other results of like nature, the question arises whether, in a dry summer, it is worth while to trouble about the aftermath of the seeds or clover ley (unless wanted for clover seed), and whether it would not be better to take the first cut early and plough up immediately so as to secure a long bastard fallow before the next corn crop. Under dry conditions the aftermath may be worth only little, while the benefit of the fallow is great. The practical difficulty on a heavy loam like ours consists in breaking up a hard baked ley at midsummer sufficiently quickly to avoid interference with other work. Not only for this purpose, but for the general object of being well forward in autumn, there is great need on medium sized heavy-land farms of a plough which will cheaply and efficiently do more than the one acre a day that has for untold years been considered the ploughman's proper and sufficient duty.

MIXED CROPS.

The harmful effect of some growing crops on others observed by Mr. Pickering, at Woburn, gives an added interest to the study of weeds. Hitherto it has been supposed that weeds are mainly harmful through depriving the plant of water, food, and root space, but Mr. Pickering's observations indicate that there is something more. Pot experiments have therefore been started and careful field observations taken to ascertain the importance of these effects in practice. We must know the real case against weeds before we can decide how much it is worth spending in order to eliminate them.

It does not always appear that one crop injures another. It is not uncommon in the west country for farmers to grow a mixture of oats and barley as dredge corn, and it is commonly stated that the yields are larger than when the two are grown separately. An experiment with the mixture has therefore been made at Rothamsted

during the past three years, and it was found to yield *exactly the same* as the mean of the two cereals grown separately during the first two years, and in the third year the comparison was vitiated by the failure of the oat crop.

If there was an ill effect at any period it must have been counterbalanced later, and in the end there was neither the decrease of crop expected from some of the pot observations, nor the increase claimed by the growers. To some extent the experiment is affected by the difficulty of growing spring oats at Rothamsted, and it would be a great advantage to have the experiment conducted in a district where the mixture is said to be a success.

There is evidence, however, that the sowing of a leguminous crop with corn leads to an increase in the latter crop.

Thus we have the three cases: (1) Mr. Pickering's observations certainly indicate that one growing plant has a directly harmful effect on another; (2) the dredge corn experiments indicate that no such effect is finally produced; and (3) other experiments indicate an actual beneficial effect when one of the crops is a leguminous crop. It is very necessary to clear up these apparent discrepancies, and a series of experiments is in hand for the purpose.

DATES OF SOWING AND HARVESTING, 1914.

(*For Meteorological data, see page 34*).

Field.	Crop.	Variety.	Sowing began.	Cutting began.	Carting began.	Carting finished.	Yield.
Great Knott Wood ...	Wheat	Squarehead's Master	Nov. 28, '13	Aug. 13	Aug. 18	Aug. 19	3 qrs.
,, ,, ...	Barley	Plumage Cross	Apr. 8 ...	Aug. 15	Aug. 25	Aug. 28	see p. 41
Little Knott Wood ...	Clover Mixture ...	Red, Alsike and Bents ...	Apr. 24, '13	June 25	June 30	June 30	
				Sept. 1	Sept. 3	Sept. 3	
,, ,, ...	Trifolium ...	Early Red	Sept. 22, '13	June 2	June 18	June 18	
Fosters	Oats	Grey Winters	Oct. 13, '13	July 20	Aug. 1	Aug. 3	$6\frac{3}{4}$ qrs.
,, ...	Wheat	Squarehead's Master	Nov. 4, '13	Aug. 12	Aug. 17	Aug. 17	$3\frac{1}{2}$,,
West Barn	Barley	Plumage Cross	Apr. 18 ...	Aug. 29	Sept. 4	Sept. 5	
Long Hoos	Oats	Grey Winters	Oct. 3, '13	July 17	July 31	July 31	$8\frac{3}{4}$,,
,, ...	Wheat	Squarehead's Master	Nov. 25, '13	Aug. 13	Aug. 15	Aug. 15	4 ,,
,, ...	,, ...	,, ,, ...	Oct. 24, '13	July 31	Aug. 14	Aug. 14	6 ,,
,, ...	Dredge	Plumage Cross Barley Grey Winter Oats	Apr. 25 ...	Sept. 2	Sept. 19	Sept. 19	see p. 40
Hoos	Barley	Archer's Stiff Straw	Apr. 14 ...	Aug. 25	Aug. 31	Sept. 1	,, 37
,, (leguminous) ...	,, ...	,, ,, ...	Apr. 14 ...	Aug. 29	Sept. 19	Sept. 19	,, 42
,, (potato barley) ...	,, ...	,, ,, ...	Apr. 22 ...	Sept. 2	Sept. 19	Sept. 19	,, 37
Little Hoos	,, ...	Plumage Cross	Apr. 13 ...	Aug. 19	Aug. 28	Aug. 28	,, 38
,, (green manure)	,, ...	,, ,, ...	Apr. 22 ...	Sept. 2	Sept. 19	Sept. 19	,, 42
Broadbalk	Wheat	Squarehead's Master	Oct. 19, '13	Aug. 11	Aug. 26	Aug. 26	,, 36
Sawpit	Oats	Grey Winters	Oct. 2, '13	July 21	Aug. 7	Aug. 11	$6\frac{3}{4}$ qrs.
Stackyard	Brussels Sprouts	Sutton's Matchless, etc. ...	June 16 (1)	Nov. 14	—	—	
New Zealand	Grass	———	——	June 27	June 29	June 29	
Great Harpenden ...	Mangolds ...	Sutton's Yellow Globe ...	May 16 ...	—	Nov. 5	Nov. 27	$18\frac{1}{2}$ tons
,, ...	Potatoes	Arran Chief, King Edward VII, Dalhousie, Scottish Farmer, Factor, Cora, Northern Star	Apr 29 ...	—	Sept. 25	Oct. 29	7 to 10 tons
Park	Grass	———	——	June 23	June 25	June 26	see p. 35
Great (N)	,, ...	———	——	June 29	July 3	July 4	,, 39
Barn	Mangolds ...	Sutton's Yellow Globe ...	May 8 ...	—	Oct. 12	Oct. 21	,, 34
Agdell	Clover	Red	Apr. 24, '13	July 10	July 13	July 13	,, 33

(1) Setting out.

CROP YIELDS ON THE EXPERIMENTAL PLOTS.

1 acre	=	0·404 Hectare.
1 bushel	=	0·364 Hectolitre.
1 lb. (pound avoir.)	=	0·453 Kilogramme.
1 cwt. (hundredweight)	=	50·8 Kilogrammes.
1 bushel per acre	=	0·9 Hectolitre per Hectare.
1 lb. per acre	=	1·12 Kilogramme per Hectare.
1 cwt. per acre	=	125·6 Kilogrammes per Hectare or 1·256 metric Quintals per Hectare.

Crops Grown in Rotation. Agdell Field.

PRODUCE PER ACRE.

Year.	CROP.	O. Unmanured.		M. Mineral Manure.		C. Complete Mineral and Nitrogenous Manure.	
		5. Fallow.	6. Beans or Clover.	3. Fallow.	4. Beans or Clover.	1. Fallow.	2. Beans or Clover.
SIXTEENTH COURSE, 1908-11.							
1908	Roots (Swedes) Cwt.	21·6	6·4	179·0	235·8	395·4	314·0
1909	Barley Grain ... Bus.	11·4	10·0	17·4	22·1	26·8	33·4
	Barley Straw ... Cwt.	10·1	11·3	12·7	16·9	18·7	23·8
1910	Clover Hay 1st crop Cwt.	—	1·6	—	24·1	—	32·2
	Clover Hay 2nd crop Cwt.	—	15·8	—	40·0	—	44·5
1911	Wheat Grain ... Bus.	23·9	24·5	31·9	37·8	33·3	38·0
	Wheat Straw ... Cwt.	20·4	21·4	28·6	33·5	29·3	32·5
PRESENT COURSE (17th), 1912-							
1912	Roots (Swedes) Cwt.	8·2	2·3	151·7	251·9	586·6	463·0
1913	Barley Grain ... Bus.	18·5	24·6	24·7	33·2	22·0	32·5
	Barley Straw ... Cwt.	8·2	13·0	10·6	14·5	9·0	15·0
1914	Clover Hay ... Cwt. (1 crop)	—	4·1	—	6·5	—	3·9

Meteorological Records, 1914.

(*See "Guide," 1913, page 18, Table IX.*)

	Rain. Total Fall. 5-inch Funnel Gauge.	Rain. Total Fall. $\frac{1}{1000}$ Acre Gauge.	Rain. No. of Rainy Days. $\frac{1}{1000}$ Acre Gauge.	Drainage through soil. 20 ins. deep.	Drainage through soil. 40 ins. deep.	Drainage through soil. 60 ins. deep.	Bright Sun-shine.	Temperature. Max.	Temperature. Min.
	Inches.	Inches.	No.	Inches.	Inches.	Inches.	Hours.	°F.	°F.
Jan. ...	0·840	0·883	15	0·677	0·648	0·653	43·8	41·7	31·9
Feb. ...	3·273	3·452	17	2·936	2·919	2·908	76·8	50·0	36·0
March ...	4·278	4·432	25	3·489	3·455	3·379	100·4	49·4	35·9
April ...	1·089	1·151	8	0·393	0·471	0·464	231·4	59·2	37·6
May ...	1·326	1·415	11	0·005	0·028	0·034	186·2	60·8	42·3
June ...	1·595	1·716	9	0·224	0·264	0·260	249·1	67·9	47·7
July ...	1·437	1·570	14	0·005	0·015	0·017	168·5	69·8	52·8
August ...	1·464	1·591	13	0·083	0·084	0·062	174·1	70·5	52·1
Sept. ...	1·164	1·298	9	—	—	—	201·7	66·2	45·2
Oct. ...	2·319	2·533	12	1·056	0·989	0·968	82·7	57·7	43·5
Nov. ...	2·767	3·099	24	2·394	2·224	2·227	70·1	50·8	37·5
Dec. ...	7·514	8·107	25	8·141	7·934	7·667	42·1	45·8	35·4
Total or Mean	29·066	31·247	182	19·403	19·031	18·639	1626·9	57·5	41·5

For dates of sowing, etc., see page 32.

Mangolds, Barn Field, 1914.

(*See "Guide," 1913, page 13, Table VI.*)

Strip.	Strip Manures.		Cross Dressings. O. None.	N. Nitrate of Soda.	A. Ammonium Salts.	A.C. Rape Cake & Ammonium Salts.	C. Rape Cake.
			Tons.	Tons.	Tons.	Tons.	Tons.
1	Dung only ...	R.	**9·82**	**17·91**	**12·92**	**10·91**	**12·51**
		L.	2·76	4·98	4·70	4·50	4·71
2	Dung, Super., Potash	R.	**8·79**	**13·93**	**14·81**	**12·33**	**14·55**
		L.	2·66	5·01	4·82	4·88	4·84
4	Complete Minerals	R.	**1·96**	**8·90** / 3·45	**8·03**	**14·04**	**14·45**
		L.	0·69	**8·34** / 3·08	2·46	4·82	3·17
5	Superphosphate only	R.	**2·01**	**9·63**	**2·61**	**3·74**	**4·06**
		L.	0·71	2·69	1·89	2·22	2·07
6	Super. and Potash	R.	**1·83**	**7·62**	**8·99**	**12·77**	**11·39**
		L.	0·69	2·90	2·82	4·79	2·87
7	Super., Sulph., Mag. & Chloride Sodium	R.	**2·64**	**8·69**	**9·20**	**12·67**	**13·66**
		L.	0·85	3·28	2·77	5·15	3·48
8	None	R.	**2·17**	**3·74**	**1·43**	**2·87**	**3·05**
		L.	0·91	2·39	1·37	2·68	1·95

R = roots. L = leaves. Tons per acre in all cases.

Hay. The Park Grass Plots, 1914.

(See "Guide," 1913, page 21, Table XI.)

Plot.	Manuring.	Yield of Hay per acre. 1914. 1st Crop.	2nd Crop.	Total.	Average 57 years 1856-1912 (1st & 2nd crops).
		cwt.		cwt.	cwt.
3	Unmanured	8·5	No 2nd Crop in 1914.	8·5	20·9
12		12·6		12·6	23·9
2	Unmanured; Dung 8 years, 1856-63	9·9		9·9	28·6
5-1	(N. half) Unmanured; following Amm. Salts alone, 42 yrs., 1856-97	6·6		6·6	14·4 (1)
1	Amm. Salts alone; with Dung 8 yrs., 1856-63	11·9		11·9	35·9
17	Nitrate of Soda alone	23·3		23·3	33·7
4-1	Superphosphate of Lime	9·9		9·9	21·6
8	Mineral Manure without Potash ...	12·6		12·6	28·0
7	Complete Mineral Manure	22·8		22·8	40·9
5-2	(S. Half) Complete Mineral Manure; following Amm. Salts alone for 42 yrs., 1856-97	14·7		14·7	23·2 (1)
6	Complete Mineral Manure as plot 7; following Amm. Salts alone 13 yrs., 1856-68	25·0		25·0	37·2
15	Complete Mineral Manure as plot 7; following Nitrate of Soda alone 18 yrs., 1858-75	26·9		26·9	36·8
4-2	Superphosphate and Amm. Salts ...	18·5		18·5	33·5
10	Mineral Manure (without Potash) and Amm. Salts	21·7		21·7	47·7
9	Complete Mineral Manure and Amm. Salts	33·6		33·6	54·3
11-1	Complete Mineral Manure and extra Amm. Salts	53·1		53·1	66·5
11-2	As plot 11-1 and Silicate of Soda ...	53·6		53·6	73·3
16	Complete Mineral Manure and Nit. Soda = 43 lb. N.	37·5		37·5	46·3
14	Complete Mineral Manure and Nit. Soda = 86 lb. N.	47·8		47·8	56·9
13	Dung and Fish Guano, once in 4 years	32·6		32·6	—

(1) 15 years, 1898—1912.

Botanical Composition, Per Cent.

First Crop, 1914.

(See "Guide," 1913, page 22, Table XII.

Plot.	Manuring.	Gramineæ.	Leguminosæ.	Other Orders.
		Per cent.	Per cent.	Per cent.
3	Unmanured	64·3	8·6	27·1
4-2	Superphosphate and Amm. Salts	99·2	—	0·8
8	Mineral Manure without Potash	69·6	9·6	20·8
7	Complete Mineral Manure ...	72·6	19·8	7·6
10	As 8 + Amm. Salts	99·7	—	0·3
9	As 7 + Amm. Salts	99·0	—	1·0
15	As 7, 1876 and since	59·5	33·1	7·4

These results were obtained on the limed portions of the plots except 15.

Wheat. Broadbalk Field, 1914.

(See "Guide," 1913, page 30, Table XVI.)

Plot.	Manuring.	Dressed Grain.		Straw per Acre.	Average for 61 years, 1852-1912.	
		Yield per Acre.	Weight per Bushel.		Dressed Grain per Acre.	Straw per Acre.
		Bushels	lb.	cwt.	Bushels.	cwt.
2	Farmyard Manure	30·7	62·2	36·6	35·2	34·8
3	Unmanured	5·8	60·6	5·1	12·6	10·3
5	Complete Mineral Manure	9·8	61·4	7·7	14·5	12·1
6	As 5, and single Amm. Salts ...	16·9	62·6	16·0	23·2	21·4
7	As 5, and double Amm. Salts ...	23·4	62·2	27·3	32·1	32·9
8	As 5, and treble Amm. Salts ...	27·7	62·1	41·9	36·6	41·1
9	As 5, and single Nitrate Soda ...	18·7	62·0	19·8	—	—
10	Double Amm. Salts alone	12·0	62·1	12·6	20·0	18·4
11	As 10, and Superphosphate	14·9	61·8	16·1	22·9	22·3
12	As 10, and Super. and Sulph. Soda	22·7	62·7	22·0	29·1	28·0
13	As 10, and Super. and Sulph. Potash	19·2	62·4	21·6	31·0	31·5
14	As 10, and Super. and Sulph. Mag.	14·6	61·9	17·0	28·8	28·0
15	Double Amm. Salts in Autumn, and Minerals	19·5	62·3	22·6	29·9	29·7
16	Double Nitrate and Minerals ...	19·2	62·3	26·1	—	—
17	Minerals alone, or double Amm. Salts	*15·9	*62·2	*19·6	*29·9	*29·5
18	alone, in alternate years	†5·3	†62·4	†4·5	†14·9	†13·0
19	Rape Cake alone	9·5	62·5	12·0	25·4 (2)	25·7 (2)

* Produce by Ammonium Salts. † Produce by Minerals.

(1) Commenced in 1906. (2) 20 years, 1893—1912.

NOTE.—As in the two previous seasons, (1912 and 1913), owing to the foulness of the land on the upper half of the field, the produce here recorded was that obtained on the lower half of the field only. (See notes on the crop at p. 7.)

Wheat after Fallow (without Manure 1851 and since). Hoos Field, 1913 and 1914.

(See "Guide," 1913, page 44, Table XXI.)

		1913	1914	Average 57 years 1856-1912
Dressed Grain	Yield—Bushels per Acre	8·3	14·9	16·0
	Weight per Bushel ...	61·8	62·7	59·4
Straw	cwt. per Acre	6·7	11·9	13·7
Total produce	lb. per Acre	1284	2351	2536

Permanent Barley Plots. Hoos Field, 1914.

(*See "Guide," 1913, page 37, Table XVIII.*)

Plot	Manuring.	1914.			Average 60 years, 1852—1911.	
		Dressed Grain.	Weight per Bushel.	Straw.	Dressed Grain.	Straw.
		Bushels.	lb.	cwt.	Bushels.	cwt.
1 O	Unmanured	10·4	53·1	5·5	12·7	8·4
2 O	Superphosphate only	13·1	53·8	6·4	19·7	10·0
3 O	Alkali Salts only	10·4	54·4	7·5	15·2	8·8
4 O	Complete Minerals	15·6	54·3	9·2	19·7	11·1
1 A	Ammonium Salts only	22·6	53·6	11·9	25·5	14·7
2 A	Superphosphate and Amm. Salts ...	28·4	53·4	14·6	38·2	22·0
3 A	Alkali Salts ,, ,, ,, ...	27·4	53·6	16·0	28·0	16·9
4 A	Complete Minerals ,, ,, ...	32·9	54·9	19·3	41·5	25·0
1 AA	Nitrate of Soda only	22·5	52·2	14·6	29·3	17·8
2 AA	Superphosphate and Nitrate Soda ...	33·4	52·8	18·9	43·1	26·3
3 AA	Alkali Salts ,, ,, ,, ...	23·7	52·5	15·7	30·0	19·3
4 AA	Complete Minerals ,, ,, ...	33·4	53·1	19·9	42·7	27·3
1 AAS	As Plot 1 AA and Silicate of Soda	24·1	52·9	15·7	32·8 (1)	19·7 (1)
2 AAS	,, ,, 2 AA ,, ,, ...	32·0	52·8	19·6	42·3 (1)	26·0 (1)
3 AAS	,, ,, 3 AA ,, ,, ...	25·9	52·3	17·6	35·2 (1)	21·7 (1)
4 AAS	,, ,, 4 AA ,, ,, ...	31·7	53·3	20·4	43·6 (1)	27·7 (1)
1 C	Rape Cake only	30·1	53·6	16·0	38·3	22·1
2 C	Superphosphate and Rape Cake ...	33·8	53·9	17·6	40·5	23·6
3 C	Alkali Salts ,, ,, ,, ...	24·2	52·8	15·1	36·9	22·3
4 C	Complete Minerals ,, ,, ...	30·0	53·4	15·8	40·5	24·5
7—1	Unmanured (after dung 20 years, 1852—71)	19·8	54·0	11·1	24·8 (2)	14·8 (2)
7—2	Farmyard Manure	40·4	55·1	23·0	47·1	29·6

(1) 48 years, 1864—1911. (2) 40 years, 1872—1911.
NOTE.—The whole of the above plots were fallowed in 1912.

Barley. Hoos Field, 1914.

(*See "Guide," 1913, page 43, Table XX.*)

Plot.	Manures applied to the Potatoes, 1876-1901. Unmanured since.	Dressed Grain.		Straw per Acre.	Total Produce per Acre.
		Yield per Acre.	Weight per Bushel.		
Previous Cropping: Potatoes, 1876-1901; Barley, 1902 and 1903; Oats, 1904; Barley, 1905-1911; Oats, 1912; Barley, 1913.					
		Bushels.	lb.	cwt.	lb.
1	Unmanured	8·8	52·4	4·8	1071
2	Unmanured 1882 to 1901, previously Dung only ...	13·4	53·4	8·9	1824
3	Dung 1883 to 1901	19·0	53·3	12·0	2504
4	Dung 1883 to 1901	20·3	53·0	14·0	2791
Previous Cropping: Potatoes, 1876-1901; Barley, 1902-1903; Oats, 1904; Plots 5, 7, 9, Cow Peas (failed), 1905; Plots 6, 8, 10, Red Clover, 1905; 1906-1911, all Plots Red Clover; Oats, 1912; Barley, 1913.					
5	Ammonium Salts	13·9	52·6	9·0	1863
6	Nitrate of Soda	15·5	52·3	10·0	2070
7	Ammonium Salts and Mixed Minerals	21·6	52·5	14·0	2864
8	Nitrate of Soda and Mixed Minerals	24·0	53·2	15·3	3125
9	Superphosphate	18·6	52·5	11·0	2317
10	Mixed Minerals	20·6	52·7	12·6	2637

RESIDUAL VALUE OF VARIOUS MANURES.

(*See "Guide," 1913, pages 45—47.*)

Little Hoos Field, 1914.

BARLEY—Produce per acre. Crop cut August 19 and 20; Carted, August 28.

Plot.		Manuring.	Dressed Grain: Bushels	Dressed Grain: Wgt. per bushel	Straw.	Total Produce.	Proportion of Offal to 100 of Dressed Grain.	Proportion of Grain to Straw as 100.
				lb.	cwt.	lb.		
(A) Dung (ordinary)	1	Unmanured	20·4	53·8	11·9	2633	18·6	97·7
	2	*a*	34·0	54·6	19·0	4202	11·7	97·4
	3	*b*	42·3	55·3	22·5	5074	9·2	101·0
	4	*c*	46·0	55·4	24·1	5547	11·4	104·8
	5	*d*	36·2	55·1	18·8	4359	13·2	107·6
(B) Dung (cake fed)	1	*a*	29·6	54·6	18·1	3880	14·7	91·7
	2	Unmanured	24·0	54·5	14·0	3097	17·1	98·0
	3	*b*	42·0	55·1	25·0	5409	12·8	93·2
	4	*c*	46·2	54·6	24·5	5579	12·1	103·0
	5	*d*	36·4	55·0	21·0	4572	11·3	94·7
(C) Shoddy ...	1	*a*	18·1	53·7	11·0	2439	24·0	97·9
	2	*b*	20·5	54·6	12·4	2769	23·3	99·5
	3	Unmanured	20·7	54·8	12·8	2805	21·4	96·4
	4	*c*	34·2	55·6	20·6	4516	16·4	96·0
	5	*d*	24·8	54·7	14·6	3215	16·4	96·0
(D) Guano ...	1	*a*	15·3	51·6	10·2	2191	33·1	91·5
	2	*b*	22·1	54·6	12·8	2865	18·5	100·0
	3	*c*	43·7	55·2	24·4	5592	18·6	104·7
	4	Unmanured	23·9	54·4	14·2	3113	17·4	96·0
	5	*d*	19·3	55·1	10·8	2513	22·5	107·3
(E) Rape Cake	1	*a*	17·8	54·7	12·4	2639	28·9	90·6
	2	*b*	28·9	55·4	18·0	3987	22·9	97·7
	3	*c*	36·0	55·3	20·0	4726	24·6	110·6
	4	*d*	22·5	54·4	14·0	3070	22·2	94·8
	5	Unmanured	19·3	53·4	12·1	2609	21·4	92·4
(F) Superphosphate	1	Unmanured	23·3	53·9	17·0	3487	26·1	83·1
	2	*a*	26·7	54·8	16·4	3602	20·6	95·8
	3	*b*	31·1	55·1	17·2	3931	17·1	104·1
	4	*c*	37·3	54·9	20·6	4735	18·4	105·1
	5	*d*	31·5	54·9	17·8	4093	21·9	105·9
(G) Bone Meal ...	1	*a*	25·6	54·1	18·6	3803	24·6	82·8
	2	*b*	25·4	53·9	19·4	3847	22·2	77·1
	3	Unmanured	28·6	53·8	21·7	4289	21·0	76·6
	4	*c*	32·1	55·3	22·5	4630	18·8	83·6
	5	*d*	33·2	53·9	22·3	4595	17·3	84·3
(H) Basic Slag ...	1	*a*	33·4	54·8	21·4	4532	16·6	88·8
	2	*b*	37·3	54·4	22·4	4862	15·9	93·5
	3	*c*	38·1	54·7	24·0	5135	17·1	90·7
	4	*d*	33·1	54·2	21·7	4519	16·5	86·1
	5	Unmanured	30·4	54·0	23·3	4600	21·2	76·1

a received its dressings in 1904, 1908, 1912. *c* received its dressings in 1906, 1910, 1914.
b ,, ,, ,, 1905, 1909, 1913. *d* ,, ,, ,, 1907, 1911, 1915.

TRIALS WITH VARIOUS NITROGENOUS MANURES.

Potatoes. Great Harpenden Field, 1914.

Plots.	Manuring.	Produce per Acre.
		Tons.
1	12 tons Dung	7·1
2	12 tons Dung, 3 cwt. Superphosphate and 1¼ cwt. Mur. Potash	7·2
3	As 2 and 175 lb. Nitrolim	8·7
4	As 2 and 220 lb. Nitrate of Lime	8·6
5	As 2 and 80 lb. Nitrate of Ammonia	9·0

The dressings of Nitrolim, Nitrate of Lime, and Nitrate of Ammonia each contained 27 lb. of Nitrogen.

Mangolds. Great Harpenden Field, 1914.

Manuring.	Series A.	Series B.
	Tons.	Tons.
12 tons Dung, 3 cwt. Superphosphate and ¾ cwt. Muriate Potash and ½ cwt. Salt	17·5	18·1
As 1 and 175 lb. Nitrolim	17·9	18·8
As 1 and 220 lb. Nitrate Lime	20·1	21·8
As 1 and 80 lb. Nitrate Ammonia	18·3	19·1

The Nitrolim, Nitrate of Lime and Nitrate of Ammonia each contained 27 lb. Nitrogen.

Oats (Grey Winter). Sawpit Field, 1914.

Manuring.	Dressed Grain.		Straw per Acre.	Total Produce per Acre.
	Yield per Acre.	Weight per Bushel.		
	Bushels.	lb.	cwt.	lb.
Control—Unmanured ...	41·3	43·8	19·7	4040
106·6 lb. Nitrolim	46·0	43·7	25·7	4903
106·6 lb. Nitrate of Soda ...	44·1	43·6	24·7	4708

The Nitrolim and Nitrate of Soda each contained 16·7 lb. Nitrogen.

Meadow Hay. Great Field, 1914.

Manuring.	Hay per Acre (1 crop).
	cwt.
Control—7½ cwt. Basic Slag	17·6
Ditto and 1136 lb. No. 1 Sludge (dried) ...	18·6
Ditto and 1290 lb. No. 2 Sludge (de-greased) ...	16·2
Ditto and 129 lb. Nitrate Soda	25·9
Ditto and 129 lb. Nitrolim	21·5

The Sludges, Nitrate of Soda and Nitrolim each contained 20 lb. of Nitrogen.

TRIALS WITH VARIOUS NITROGENOUS MANURES.—Contd.

Oats (Grey Winter). Sawpit Field, 1914.

Manuring.	Dressed Grain.		Straw per Acre.	Total Produce per Acre.
	Yield per Acre.	Weight per Bushel.		
	Bushels.	lb.	cwt.	lb.
Control—Unmanured	41·3	43·8	19·7	4040
946 lb. No. 1 Sludge (dried) ...	36·3	44·1	17·9	3614
1076 lb. No. 2 Sludge (de-greased) ...	37·4	44·5	19·1	3815
106·6 lb. Nitrate Soda	44·1	43·6	24·7	4708

The Sludges and the Nitrate of Soda each contained 16·7 lb. Nitrogen.

EXPERIMENTS IN SOIL MANAGEMENT.

FALLOWING.

	Dressed Grain.		Straw per Acre.	Total Produce per Acre.
	Yield per Acre.	Weight per Bushel		
Oats (Grey Winter). Sawpit Field, 1914.				
	Bushels.	lb.	cwt.	lb.
Fallow after Dredge Corn	67·7	44·9	41·5	7743
No fallow—Wheat and Potatoes previously	37·1	44·6	18·3	3747
Wheat (Square Head's Master). Broadbalk Field, 1914.				
Fallow after Lucerne	31·2	63·9	31·0	5740

The Broadbalk results compare with those on p. 36.

MIXED CROPS

Sawpit Field, 1912. Little Knott Wood Field, 1913. Long Hoos Field, 1914.

Crop.	Dressed Grain. Yield.			Weight per Bushel.			Straw.			Total Produce.		
	1912.	1913.	1914.	1912.	1913.	1914.	1912.	1913.	1914.	1912.	1913.	1914.
	Bushels	Bushels	Bushels	lb.	lb.	lb.	cwt.	cwt.	cwt.	lb.	lb.	lb.
Oats & Barley	27·7	26·2	21·7	49·0	50·5	46·2	26·3	15·2	19·6	4318	3046	3240
Oats alone	17·3	19·7	6·4	33·1	41·2	33·0	26·4	12·2	11·4	3593	2200	1531
Barley alone	36·2	32·4	17·0	50·5	53·6	53·7	26·8	18·4	13·9	5081	3800	2666

Crops grown after Swedes; no manure was given.

Experiments in Soil Management.—Contd.

CHALKING.

Barley (Plumage Cross). Great Knott Wood Field, 1913 and 1914.

	Dressed Grain.				Straw.		Total Produce.	
	Yield.		Weight per Bushel.					
	1913.	1914.	1913.	1914.	1913.	1914.	1913.	1914.
	Bushels	Bushels	lb.	lb.	cwt.	cwt.	lb.	lb.
Unchalked ...	59·4	30·3	54·5	53·8	24·1	17·6	5994	3990
Chalked ...	68·2	28·8	54·6	53·5	26·6	19·2	6760	4053

Both plots manured with ¾ cwt. Sulphate Ammonia and 2½ cwt. Superphosphate per acre in 1913, and in 1914 1 cwt. Sulphate Ammonia and 2 cwt. Superphosphate.

Oats (Grey Winter). Sawpit Field, 1914.

	Dressed Grain.		Straw per Acre.	Total Produce per Acre.
	Yield per Acre.	Weight per Bushel.		
After Fallow and Dredge Corn :	Bushels.	lb.	cwt.	lb.
20 loads Carted Chalk (1) ...	37·3	43·9	32·3	5351
50 loads Dug Chalk (2) ...	41·1	44·1	38·4	6159
Unchalked	44·6	44·1	35·7	6006

(1) From excavations for Harpenden Sewage Beds. (2) From Rothamsted Fields.

Potatoes (Dalhousie). Great Harpenden Field, 1914.

Dressings.	Tons per acre.				Mean.
Unchalked	8·9	8·7	9·8	9·6	9·3
Chalked (about 20 loads per Acre)	9·0	8·5	—	—	8·8

SUBSOILING.

Potatoes (King Edward VII). Great Harpenden Field, 1914.

	Ploughed & Subsoiled.		Ploughed only.	
	Tons.		Tons.	
Chalked (about 20 loads per acre)	7·2		6·7	
Unchalked	7·2	Mean 7·4	6·2	Mean 6·9
,, ...	8·0		7·0	
,, ...	7·2		7·7	
,, ...	7·1		6·7	

VARIOUS TRIALS.

SULPHATE OF MANGANESE AS A MANURE.

Mangolds. Great Harpenden Field, 1914.

Plot.	Manuring.	Without Sulphate of Manganese.	With 35 lb. Sulphate of Manganese per Acre.
		Tons.	Tons.
1	12 tons Dung, 3 cwt. Superphosphate, ⅝ cwt. Muriate Potash and ½ cwt. Salt	18·1	16·6
2	As No. 1 and 175 lb. Nitrolim	18·8	17·2
3	As No. 1 and 220 lb. Nitrate of Lime	21·8	20·4
4	As No. 1 and 80 lb. Nitrate of Ammonia	19·4	18·4*

The Nitrolim, Nitrate of Lime and Nitrate of Ammonia each contained 27 lb. Nitrogen.

* In this case 25 lb. of Sulphate of Manganese was applied per acre.

Little Hoos Field Green Manured Plots. Barley, 1914.

Previous Crops: Green Manuring, 1904-6, 1908 and 1909, 1911, 1913; Wheat, 1907, 1910, 1912.

Green Crop	Dressed Grain.		Straw per Acre.	Total Produce per Acre.
	Yield per Acre.	Weight per Bushel.		
	Bushels.	lb.	cwt.	lb.
Rape	18·9	53·1	15·4	3001
Crimson Clover	15·0	51·4	14·0	2625
Vetches	21·5	52·1	18·9	3555
Mustard	18·8	53·0	15·1	2981

Barley. Hoos Field Leguminous Plots, 1914.

	Dressed Grain.		Straw per Acre.	Total Produce per Acre.
	Yield per Acre.	Weight per Bushel.		
	Bushels.	lb.	cwt.	lb.
After Lucerne	33·0	53·5	17·6	3853
,, Red Clover	20·3	53·3	10·6	2347
,, Alsike Clover	21·9	53·9	11·3	2522

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